Dynamics of *Betula ermanni* population in subalpine vegetation in Changbai Mountain, Northeast China[1]

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Abstract: *Betula ermanni* population was divided into three groups: the upper population (2 000~2 200 m), the middle population (1 700~2 000 m), and the down population (1 400~1 700 m) in Changbai Mountain. The dynamics of *Betula ermanni* populations in subalpine vegetation are studied and the population life table, fecundity schedule, survival curves, age structure, and fecundity curves were established. The results showed that the middle population is obviously the transition from the upper population to the down population.

Key words: Dynamics, *Betula ermanni*, Subalpine vegetation, vegetation boundary, Ecotone, Changbai Mountains, Life table, Age structure, Fecundity schedule

Introduction

Not only are timberlines the most conspicuous vegetation boundary in high mountains, but they are also an important ecological boundary (Bruce 1996; Thomas 1997). No wonders then those timberlines have always attracted researchers for both scientific and practical reasons. In Changbai Mountain, for example, the restoration of the climatic timberline and establishment of an effective protective forest are the two principal objectives of high-mountain forest management. Also in this connection, the potential response of timberlines to expected climatic change has begun to be a matter of interest (Bruce *et al*. 1996; Ian *et al*. 1993).

Betula ermanni forest is one of the vegetation types in subalpine and subarctic regions, and it distributes mainly in Eastern Asia, such as Northeast China, North Japan, Far-east area of Russia, and so on (Liu & Wang 1992). Very large areas of natural *Betula ermanni* forest are in the regions of Daxing'an Mountains, Xiaoxing'an Mountains, Zhangguangcai Mountains, and Changbai Mountain of Northeast China. The distributed area of *Betula ermanni* forest in subalpine vegetation of Changbai Mountains is the largest in China and even in the world.

Betula ermanni population distributes at altitudes from 1 370 m to 2 230 m in Changbai Mountain. It is timberline vegetation, which is conspicuous vegetation boundary. In the whole distributional area of *Betula ermanni*, there are two ecotones. One is an ecotone of *Picea-Abies* species and *Betula ermanni* at 1 700 m and its proximity, and the other is an ecotone of *Betula ermanni* and tundra species at 2 000 m and its proximity.

Study sites and methods

Study area and vegetation

The study area is located in the Changbai Mountain Biosphere Reserve, in Erdaobaihe, Antu County, Jilin Province. Mean annual rainfall is 967.3~1 400 mm with only one rainy season in summer. Soil is mountain sody forest soil, which developed from volcanic ash.

The whole distribution area of *Betula ermanni* is from 1 370 m to 2 230 m in altitude. *Betula ermanni* population was divided into three groups according to the community characters: the upper population (2 000~2 200m), middle population (1 700~2 000 m), and the down population (1 400~1 700 m)

In down part, it is dark coniferous forest. The main tree species are *Picea jezoensis, Abies nephrolepis, Larix olgensis, Acer ukurunduense, Sorbus pohuashanensis,* and *Betula ermanni.* The coverage of canopy is about 90%. There are few shrub species, such as seedlings of *Acer tegmentosum, Acer ukurundüense, Ulmus propinqua,* and *Rosa dahurica,* with coverage of about 35%. Many herb species have distribution there, such as *Athyrium brevifrons, Adiantum pedatum, Listera major, Maianthemum dilataum, Pyrola renifolia, Solidago virgaurea* var. *dahurica, Cacalia hastata, Polygonatum odoratum, Fragaria orientalis, Actaea acuminata, Carex angarae, Pyrola ramischia, Rubus arctious,* and so on, with coverage of 80%~85%.

In middle part, subalpine *Betula ermanni* forest is the main forest type. There are few tree species, such as *Betula ermanni, Abies nephrolepis, Picea jezoensis,* and *Larix olgensis.* There is hardly shrub

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species under the forest, but the herb species develop very well. They are *Polygonatum odoratum, Actaea acuminata, Thalictrum squarrosum, Deyeuxia augustifolia, Solidago virgaurea* var. *dahurica, Cacalia hastata, Pyrola renifolia, Adiantum pedatum, Fragaria orientalis, Maianthemum dilataum, Saussurea tenerifolia, Rhododendron chrysanthum, Aconitum monanthum, Listera major,* and *Veratrum nigrum.* The coverage of herb species is 100%.

In upper part, the main forest type is seedling forest of *Betula ermanni* in the subalpine vegetation. *Betula ermanni* and *Larix olgensis* are the main tree species. Moreover, *Larix olgensis* exists only in seedling or abnormal state. There, however, are many undergrowth species, such as *Juncus castaneus, Euphorbia lucorum, Rhododendron chrysanthum, Dryas octopetala* var. *asiatica, Gentiana triflora, Vaccinium ulig* var. *alpin, Saussurea alpina, Polygonum ajanense* and so on, of which, some are alpine and arctic species. The coverage of undergrowth reaches 100%.

Vegetation sampling

The Peak of Changbai Mountain is 2 691 m above sea level. The vegetation varies in different zones from bottom to top because of different water, temperature conditions. *Betula ermanni* distributes from 1 370 m to 2230 m according to our investigation. From 1 370 m, it distributes in the dark coniferous forest in old-growth individual, and forms an ecotone of *Picea-Abies* species and *Betula ermanni* in 1 700 m and its proximity. Moreover, *Betula ermanni* population dispersal along altitude to 2 230 m under climatic change in the recent years and form an ecotone of *Betula ermanni* and tundra species at 2000 m and its proximity.

Sixty-one 10 m × 10-m plots and eighteen 20 m × 40 m plots were established, with 50-m altitude step, at altitudes from 1 400 m to 2 200 m in Changbai Mountain, in 1998-1999. Tree height and DBH (diameter at breast height) were investigated.

Results and analysis

Life table of *Betula ermanni* population

A life table summarizes the statistics of death and survival of a population by age. Population life table is a table of survival ratio and fecundity of individual of each age scale (Harper 1997). Life table can be divided into two kinds, and those are special age life table or dynamic life table and special time life table or stable life table. As far as woody plant is concerned, the special time life table is always established. Three hypotheses must be fitted when establishing the table. Firstly, population density is stable. Secondly, age scale of population is stable. Thirdly, the moving ratio of population is stable.

In the special time life table, there are many items with following significance:

X—age scale (one scale is 10 years);

lx—survival individuals in beginning of *X* period (normalization);

Dx—the dead individuals from *X* to *X*+1 period;

Qx—the death ratio from *X* to *X*+1 period, expressing as *Dx*/lx;

Lx—survival individuals during *X* and *X*+1 period, expressing as [*lx*+l(*X*+1)]/2;

Tx—individuals from X to more than X period;

Ex—mean expected life of survival individual from beginning of this age scale, and it is *Tx*/*lx*;

Ax—practical survival individuals in the age scale;

According to our investigation, three population life tables of *Betula ermanni* at different altitude (1 400-1 700, 1 700~2000, 2 000~2 200 m) were established (Table 1).

Based on population life table of *Betula ermanni*, in upper population the peak of death ratio of *Betula ermanni* is from 200~260 years. In middle population, the peak of death ratio is 180~210 years, and there is another peak in 250 years. In down population, the death ratio is always high from 10 to 170 years, and the maximum death ratio is 260 years. The order of mean expected life of population of these three parts is Upper > Middle > Down. In order to express the situation of population tendency, we establish the survival curve of these three populations (Fig. 1).

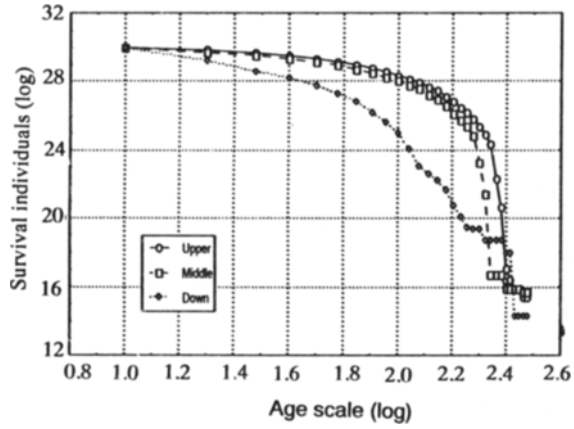

Fig. 1. Survival curve of *Betula ermanni* population

From Fig. 1, the upper group and middle group of *Betula ermanni* are increasing populations, and the down group is also a slowly increasing population. The middle population is just between the upper one and the down one. However, the curve almost crosses together with the age scale.

Table 1. Life table of *Betula ermanni* population in subalipine vegetation of Changbai Mountains

X	Lx			Dx			Qx (‰)			Lx			Tx			Ex			Ax		
	U	M	D	U	M	D	U	M	D	U	M	D	U	M	D	U	M	D	U	M	D
10	1000	100	1000	35	67	16	35.000	67.000	166.000	983	967	917	14548	12840	7906	14.548	12.84	7.906	643	541	93
20	965	93	834	34	31	11	35.233	33.226	137.890	948	918	777	13548	11840	6906	14.039	12.69	8.281	548	438	128
30	931	90	719	37	45	5	39.742	49.889	70.932	913	880	694	12583	10907	6072	13.516	12.09	8.445	435	338	126
40	894	85	668	32	41	7	35.794	47.841	106.287	878	837	633	11652	10005	5353	13.034	11.67	8.013	231	342	94
50	862	81	597	39	27	6	45.244	33.088	108.878	843	803	565	10758	9148	4685	12.480	11.21	7.848	129	279	120
60	823	78	532	30	47	5	36.452	59.569	99.624	808	766	506	9896	8332	4088	12.024	10.56	7.684	98	234	119
70	793	74	479	38	37	6	47.919	49.865	135.699	774	724	447	9073	7543	3556	11.441	10.16	7.424	64	187	95
80	755	70	414	35	38	4	46.358	53.901	111.111	738	686	391	8280	6801	3077	10.967	9.64	7.432	52	138	87
90	720	66	368	36	28	4	50.000	41.979	133.152	702	653	344	7525	6096	2663	10.451	9.13	7.236	29	135	72
100	684	63	319	29	38	6	42.398	59.468	191.223	670	620	289	6805	5429	2295	9.949	8.49	7.194	25	136	71
110	655	60	258	32	32	5	48.855	53.245	209.302	639	585	231	6121	4790	1976	9.345	7.97	7.659	25	133	66
120	623	56	204	37	40	2	59.390	70.299	102.941	605	549	194	5466	4189	1718	8.774	7.36	8.422	24	105	61
130	586	52	183	29	40	1	49.488	75.614	87.432	572	509	175	4843	3620	1514	8.265	6.84	8.273	23	98	56
140	557	48	167	38	38	2	68.223	77.710	125.749	538	470	157	4257	3091	1331	7.643	6.32	7.970	22	83	42
150	519	45	146	39	43	2	75.145	95.344	184.932	500	430	133	3700	2602	1164	7.129	5.76	7.973	20	79	33
160	480	40	119	32	36	1	66.667	88.235	142.857	464	390	111	3181	2151	1018	6.627	5.27	8.555	20	68	34
170	448	37	102	33	25	1	73.661	67.204	127.451	432	360	96	2701	1743	899	6.029	4.68	8.814	19	47	26
180	415	34	89	36	44		86.747	126.801	22.472	397	325	88	2253	1371	797	5.429	3.95	8.955	15	36	17
190	379	30	87	32	91		84.433	300.330	0.000	363	258	87	1838	1024	708	4.850	3.38	8.138	12	25	19
200	347	21	87	37	74	1	106.628	349.057	137.931	329	175	81	1459	721	621	4.205	3.40	7.138	11	24	23
210	310	13	75	39	91		125.806	659.420	0.000	291	93	75	1112	509	534	3.587	3.68	7.120	13	23	25
220	271	4	75	99	0		365.314	0.000	0.000	222	47	75	802	371	459	2.959	7.89	6.120	11	23	29
230	172	4	75	56	0		325.581	0.000	0.000	144	47	75	531	324	384	3.087	6.89	5.120	9	20	43
240	116	4	75	65	0	1	560.345	0.000	160.000	84	43	69	359	277	309	3.095	5.89	4.120	10	18	35
250	51	3	63	7	8		137.255	205.128	0.000	48	39	63	243	230	234	4.765	5.89	3.714	8	16	49
260	44	3	63	5	0	3	113.636	0.000	571.429	42	39	45	192	191	171	4.364	4.89	2.714	11	13	37
270	39	3	27	0	0		0.000	0.000	0.000	39	39	27	148	152	108	3.795	3.89	4.000	7	10	32
280	39	3	27	4	0		102.564	0.000	0.000	37	38	27	109	113	81	2.795	2.89	3.000	8	9	20
290	35	3	27	0	2		0.000	54.054	0.000	35	37	27	70	74	54	2.000	2.00	2.000	2	7	17
300	35	3	27	0	0		0.000	0.000	0.000	18	19	14	35	37	27	1.000	1.00	1.000	5	1	25

Where U represents upper population, M represents middle population, and D represents down population

Age structure analysis

Age structure of a tree species, which reflects regeneration process and velocity, means quantity of the tree species divided by age scale. According to age structure of *Betula ermanni* population (Fig. 2), in upper population, survival individuals decrease rapidly with age scale. In down population, the survival individuals decrease slowly with age scale and increase around the age of 250. In middle population, survival individuals are just between the last two populations. That is to say, the middle population is just the transition of the upper population and the down population.

Fecundity schedule analysis

Population reproductive process is an important process for studying its dynamics. Generally speaking, fecundity is one of the biological properties of a certain species. According to the references from Liu Qijing (1992) and our investigation, the production of single *Betula ermanni* tree of various age scales (from 0 to 300 years old) is almost linear. According to this, we could establish a fecundity schedule of *Betula ermanni* population (Table 2). Fecundity schedule is a useful tool for expressing produce ability of a certain population and predicting its development tendency. The data of a fecundity schedule includes five items: *X*, *Lx*, *Mx*, Lx·*Mx*, and *Lx*·*Mx*·*X*, *X*—age scale; *Lx*—the ratio of survival individuals of each age scale to that of the first age scale in the life table; *Mx*—the mean production of *Betula ermanni* in each age scale.

Some parameters can be obtained from fecundity schedule, such as R_0, T, r_m, t, λ, and so on. R_0 (net reproductive rate) is an important parameter in fecundity schedule. It expresses the increasing times of each population. T (generation length) is mean

period from birth of parents to birth of offspring. r_m is the intrinsic rate of naturally increase of a population. t is time for population doubling. λ is increasing rate of period. These parameters can be obtained from the following formulas.

$R_0=\sum Lx \cdot Mx$;
$T=(\sum Lx \cdot Mx \cdot X)/R_0$;
$r_m=\mathrm{Ln}R_0/T$;
$t=\mathrm{Ln}2/r_m=0.6931/r_m$;
$\lambda=e^{rm}$.

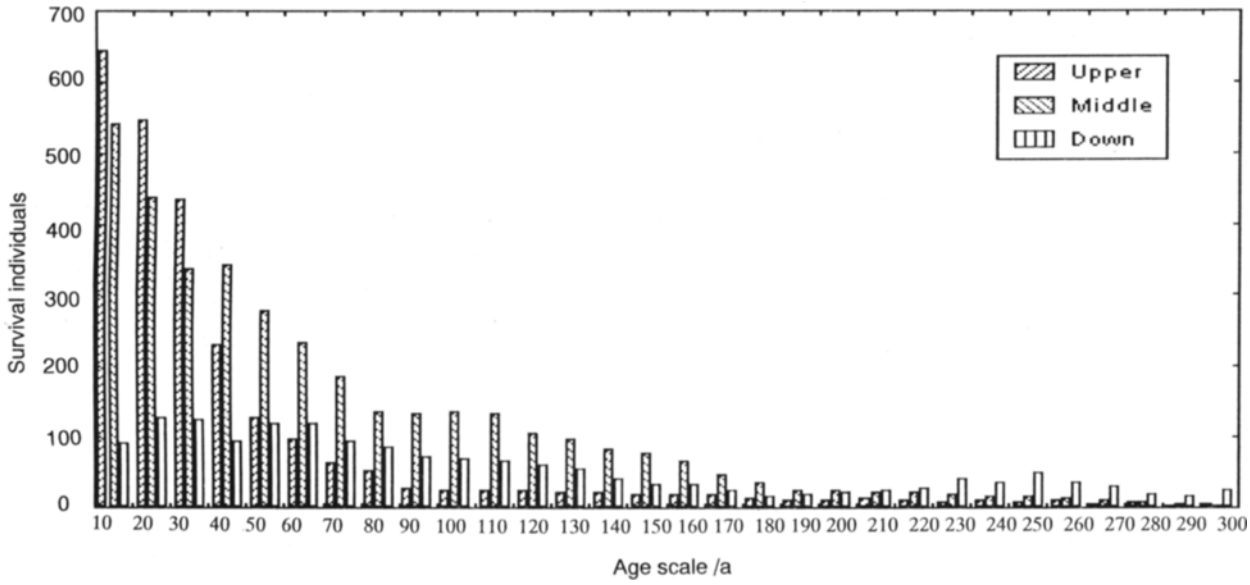

Fig. 2. Age structure of *Betula erimonii*

Table 2. Fecundity schedule of *Betula ermanni* population in subalpine vegetation of Changbai Mountain

X	*Lx*			*Mx*	*Lx·Mx*			*Lx·Mx·X*		
	U	M	D		U	M	D	U	M	D
10	1.000	1.000	1.000	0	0	0	0	0	0	0
20	0.965	0.933	0.834	0	0	0	0	0	0	0
30	0.931	0.902	0.719	0	0	0	0	0	0	0
40	0.894	0.857	0.668	0	0	0	0	0	0	0
50	0.862	0.816	0.597	43066	37123	35142	25710	1856145	1757093	1285520
60	0.823	0.789	0.532	64334	52947	50759	34226	3176813	3045572	2053541
70	0.793	0.742	0.479	89855	71255	66672	43041	4987851	4667069	3012838
80	0.755	0.705	0.414	119630	90321	84339	49527	7225652	6747132	3962146
90	0.720	0.667	0.368	153658	110634	102490	56546	9957038	9224090	5089153
100	0.684	0.639	0.319	191940	131287	122650	61229	13128696	12264966	6122886
110	0.655	0.601	0.258	234475	153581	140920	60495	16893924	15501142	6654401
120	0.623	0.569	0.204	281264	175228	160039	57378	21027297	19204706	6885343
130	0.586	0.529	0.183	332306	194731	175790	60812	25315071	22852684	7905560
140	0.557	0.489	0.167	387602	215894	189537	64729	30225204	26535233	9062135
150	0.519	0.451	0.146	447151	232071	201665	65284	34810705	30249765	9792607
160	0.480	0.408	0.119	510954	245258	208469	60803	39241267	33355077	9728564
170	0.448	0.372	0.102	579011	259397	215392	59059	44097478	36616656	10040051
180	0.415	0.347	0.089	651321	270298	226008	57968	48653679	40681510	10434162
190	0.379	0.303	0.087	727884	275868	220549	63326	52414927	41904282	12031923
200	0.347	0.212	0.087	808701	280619	171445	70357	56123849	34288922	14071397
210	0.310	0.138	0.075	893772	277069	123340	67033	58184557	25901513	14076909
220	0.271	0.047	0.075	983096	266419	46205	73732	58612184	10165213	16221084

Continue Table 2.

X	Lx			Mx	Lx·Mx			Lx·Mx·X		
	U	M	D		U	M	D	U	M	D
230	0.172	0.047	0.075	1076673	185187	50604	80750	42593184	11638835	18572609
240	0.116	0.047	0.075	1174504	136243	55202	88088	32698191	13248405	21141072
250	0.051	0.039	0.063	1276589	65106	49787	80425	16276510	12446743	20106277
260	0.044	0.039	0.063	1382927	60848	53934	87124	15820685	14022880	22652344
270	0.039	0.039	0.027	1493519	58247	58247	40325	15726755	15726755	10887754
280	0.039	0.039	0.027	1608364	62726	62726	43426	17563335	17563335	12159232
290	0.035	0.037	0.027	1727463	60461	63916	46642	17533749	18535678	13526035
300	0.035	0.037	0.027	1850815	64779	68480	49972	19433558	20544047	14991602

Note: Where U represents upper population, M represents middle population, and D represents down population

These parameters are of the fecundity schedule as follows: R_{0u}=4033597, T_u=174.43, r_{mu}=0.0872, t_u=7.9485, λ_u=1.0911, R_{0m}=3004307, T_m=165.99, r_{mm}=0.0898, t_m=7.7133, λ_m=1.0940; R_{0d}=1548007, T_d=182.47, r_{md}=0.0781, t_d=8.8735, λ_d=1.0812.

Based on fecundity schedule, the fecundity curves of different *Betula ermanni* populations are established (Fig. 3).

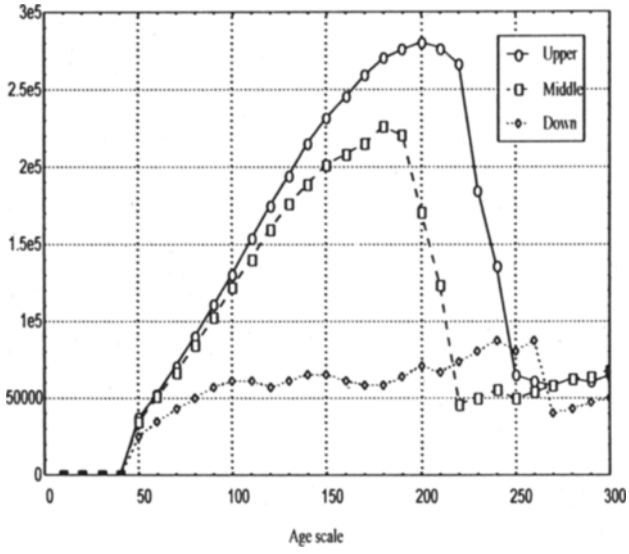

Fig 3. Fecundity off *Betula ermanni* population at different altitudes

With the altitude increasing, the fecundity of *Betula ermanni* population increases rapidly because of higher ratio of survival individuals. The fecundity peak of the upper population exists in 200 years old, and that of the middle population exists in 180 years old. However, in down population, the fecundity of *Betula ermanni* population is lower and stable after 100 years old. When individual age is over 250 years old, the fecundity of the three populations is almost identical due to their low ratio of survival individuals.

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